

An Iterated Four-Player Prisoner's Dilemma Game with an External Selecting Agent: A Metacontingency Experiment

El juego del “Dilema del Prisionero” con cuatro participantes y un agente selector externo: un experimento metacontingencial

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The first experiment was reported at the 34th annual convention for the Association for Behavior Analysis in Chicago (May, 2008). All five experiments were presented in the current graphing format at the 5th European Association for Behavior Analysis in Crete (September 2010)

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Resumen

En esta serie de experimentos utilizamos un juego iterativo del “Dilema del Prisionero” (IPDG por sus siglas en inglés) para examinar el efecto de las metacontingencias sobre los productos agregados del comportamiento interrelacionado de cuatro jugadores. Los resultados del primer experimento muestran que las consecuencias de nivel cultural (“retroalimentación del mercado” en la forma de puntos entregados a todos los jugadores), contingentes con los productos agregados XXX o YYYY aumentaron la frecuencia de esas producciones. En experimentos posteriores, añadimos una condición de línea de base en la cual los jugadores experimentaron solo las contingencias

Abstract

In these series of experiments we used an iterated prisoners' dilemma game (IPDG) to examine the effect of metacontingencies on aggregate products of the interrelated behavior of four players. Results of the first experiment showed that cultural level consequences (“market feedback” in the form of points delivered to all players) contingent on aggregate products XXXX or YYYY increased the frequency of those productions. In subsequent experiments we added a baseline condition where the players experienced only the individual behavioral contingencies embedded in the game. Then we imposed the metacontingency on the XXXX aggregate product or, alternatively, on YYYY. After

conductuales individuales incorporadas en el juego. Luego impusimos la metacontingencia sobre el producto agregado XXXX, o de forma alternativa sobre YYYY. Después de varias reversiones, descontinuamos la metacontingencia y los jugadores comenzaron a experimentar nuevamente solo las contingencias individuales del juego. En un experimento utilizamos un control para evaluar el efecto de la retroalimentación del mercado de manera independiente de la relación metacontingencial. Los resultados indican que la consecuencia cultural (retroalimentación del mercado) controló la producción de productos agregados incluso cuando su magnitud era mínima, que la relación metacontingencial era necesaria, y que mantenía relaciones en el comportamiento de los individuos que tenían los peores resultados para todos los jugadores.

Palabras: selección cultural, contingencias conductuales, contingencias culturales, contingencias conductuales entrelazadas.

several reversals, we discontinued the metacontingency and the players again experienced only the individual contingencies of the game. In one experiment we used a yoked control to assess the effect of market feedback independent from the metacontingency relation. Results indicate that the cultural consequence (market feedback) controlled production of aggregate products even when its magnitude was minimal, that the metacontingency relation was necessary, and that it maintained relations among the behavior of individuals which resulted in the worst individual outcomes for all players.

Keywords: cultural selection, behavioral contingencies, cultural contingencies, interlocking behavioral contingencies

The contingencies of reinforcement for the everyday behavior of humans often involve the behavior of other people. Skinner called these interrelations “interlocking contingencies” (Skinner, 1957, p. 432). If interlocking contingencies result in a product on which an externally controlled consequence is contingent, the relation between the interlocking contingencies and the external consequence has been called a “metacontingency” (Glenn, 2004). The experiments reported here were designed to assess the effect of metacontingency manipulations on recurring interlocking behavioral contingencies (IBCs) measured in terms of their products. This measure of a cultural unit (recurring IBCs) is analogous to using switch closures as a measure of operants (recurring responses).

Although experimental analyses of metacontingencies are underway in several laboratories in Brazil and the U.S., we are aware of only one published experiment as of this writing (Vichi, Andery & Glenn, 2009). In that study, each of four subjects (in one of two groups) “bet” on the outcome of a group choice. The experimenter manipulated metacontingencies so that the subjects won or lost their bets based on whether they had distributed earnings from the previous cycle equally (in some conditions) or unequally (in other conditions). Results showed that the equal and unequal distributions of earnings changed in accordance with the metacontingency requirement. In

post-experimental interviews, no subject described the metacontingency relations.

The current line of experiments sought to test necessary conditions for metacontingency control of IBC aggregated products using a Prisoner’s Dilemma Game (PDG) preparation. The PDG is based on a situation in which two people accused of a crime are each offered an opportunity to testify against the other. If one “turns state’s witness” and the other claims innocence, the former is released and the latter receives the full sentence. If neither testifies against the other, they both get light sentences; if both testify they both get a moderate sentence. Games of one cycle are called “one shot” Prisoner’s Dilemma Games; the form in which players engage in repeated cycles of the game is known as the Iterated Prisoner’s Dilemma Game (IPDG), which is used in the current experiments.

A typical IPDG experiment (e.g., Cooper, DeJong, Forsythe & Ross, 1996) has two players who each press either X or Y on a keyboard in each round, or game cycle. The payoff for pressing X or Y varies, depending on what the other player does in that cycle. Point deliveries are arranged so that if both players press X, both earn the same number of points; but if one player presses Y, that player earns more at the expense of the one who presses X. If they both press Y, they each get less than if both pressed X (see Table 1).

Table 1.
Example of outcomes and choices in a Prisoner's Dilemma Game with two players.

Choices P1P2	Points P1P2
XX	77
XY	010
YY	33

In the two-player IPDG, the average frequency of X presses is higher than in the one shot game. One study found a frequency of .22 in the one-shot game and .52 in the iterated game (Cooper et al., 1996). As the number of players increases, however, the mean number of X presses decreases (Bonacich, Shure, Kahan, Meeker, 1976). In a review of previous research, Dawes (1980) concluded that subjects press X less in larger groups than in smaller ones. Rapoport et al., (1962) and Bixenstine et al., (1966) noted a lower frequency of X pressing in three and six-person games as compared to two-person games. Yi and Rachlin (2004), in an IPDG with 5 players, found a very low (.2) X pressing frequency, similar to results of other experiments with five or more players. Importantly, informing players about the number of cycles they are going to play does not decrease the frequency of pressing X ["cooperation"] even though the famous "backwards induction" argument would predict so (Normann & Wallace 2011). On the other hand, allowing the players to communicate increases the frequency of X presses (Dawes, 1980). Because of this facilitating effect of verbal communication, players were allowed to communicate throughout the experiments described in this paper.

Experienced players in 2-person games typically settle into a coordinated pattern of pressing X (Selten & Stoecker, 1986). For present purposes, each player's behavior is viewed as adapting to operant contingencies with "interdependent consequences" (Schmitt, 1998). Overall, such contingencies in the IPDG dictate that players generate higher earnings over time if all consistently press X.

Even though much of the research on the Prisoner's Dilemma Game with two or more players reports data in terms of percentage of X presses (e.g., Dawes, 1980; Gallo & McClintock, 1965), we do not do so because our interest is in establishing systematic control over interrelated patterns of behavior among players across cycles. Specifically, in

the four-person experiments described here we focused on selection of XXXX and YYYY patterns as aggregate products of the IBCs of the four players. We used a reversal experimental design to test the effects of a cultural consequence on the production of these aggregate products. The consequence is designated as "cultural" because the unit established and maintained by the metacontingency is the interlocking behavioral contingencies of multiple players.

General Method

The five experiments reported here are similar in their general method. In this section, we describe those common features to all experiments. In the following sections we discuss specific procedures and results to each experiment.

Subjects

A different set of four people participated in each experiment. Participants were recruited at the University of North Texas from undergraduate classes in behavior analysis, fliers posted on campus, and ads placed in the campus newspaper.

Apparatus

Five networked personal computers were used, one for each of the four participants and one for the experimenter to collect data and change conditions in the experiment. For experiments 2-5, the experimenter used an additional computer to track responses. The computers' monitors and the participants were screened by panels so they were not visible to the other participants.

General Procedure

After participants were seated at their computers they were told that: (1) they were owners of a company, (2) the amount of money each participant would make would depend on how well they did during the experiment, and (3) they would be allowed to communicate with each other exclusively through their computers. No other instruction was provided.

A general chat window was present on the left side of each screen, and everything written on the chat window by any player or the experimenter could be seen by everyone else. Above that window, the identity of the participant

was shown (e.g. “Player 2”). The chat window remained active throughout the experiment. A counter above the chat window signaled how many seconds remained in the current interval. At the end of the countdown, the word “Interval” was replaced by the words: “Go Ahead! You Choose X or Y”. The time in seconds available to click on either X or Y with the left mouse button was indicated in the upper left corner of the screen. After the last choice was made, each player received 4 seconds of feedback on his or her own choices and earnings and everyone else’s choices and earnings. If a subject did not press X or Y within the time allowed, a random choice was made by the computer. The amount of money each press earned depended on whether the players pressed X or Y and on what the other players pressed in that cycle. Each choice was seen by every other player at the moment it was made so that it could potentially work as a discriminative stimulus for the next choice, thus allowing for the formation of interlocks. A single player could be placed on timeout for one cycle if all the other players pressed a button that said “Kick Player [x]” which appeared on the screen during the time between choices. Three such buttons appeared on each player’s screen simultaneously, one for each of the other players.

Individual Earnings	Aggregate Product	Total Payout
7 7 7 7	= YYYY	(28)
4 11 11 11	= XYYY	(37)
8 8 15 15	= XXYY	(46)
12 12 12 19	= XXXY	(55)
16 16 16 16	= XXXX	(64)

Figure 1. Correspondences between individual earnings and all possible aggregate products. The column on the left, Individual Earnings, shows the distribution of earnings in cents given the combination of presses generating the Aggregate Products shown in the middle column. The right column shows that overall earnings on any given cycle are increasingly greater the larger the number of X presses in the cycle. The top row of earnings represents a cycle in which all the players press Y. In the second row one player presses X, the others Y, and so on.

Figure 1 shows that pressing Y earned the most when all the other players pressed X. But if *everyone* pressed Y on a cycle, each player earned 7 cents, which was the second worst possible result for any player, the worst being 4 cents earned by a single player pressing X when everyone else pressed Y; the best being 19 cents earned by a single player pressing Y when everyone else pressed

X. If everyone pressed X, all players attained the second best outcome: 16 cents; Figure 1 also shows that as the number of players pressing X increases, the global gain (sum total of everyone’s gain – number in parenthesis next to the aggregate product) increases.

After the feedback on everyone’s choices appeared on the screen, either a new interval began or the action of an external selecting agent (called in the experiment “feedback from the market”) was signaled through a window appearing in the top-right part of the screen saying “Profit was x cents, you and each other player receive x/4 cents” Figure 2 shows conceptually how the action of such an external environment might select a group of interactions when contingent on the aggregate products produce those interactions.

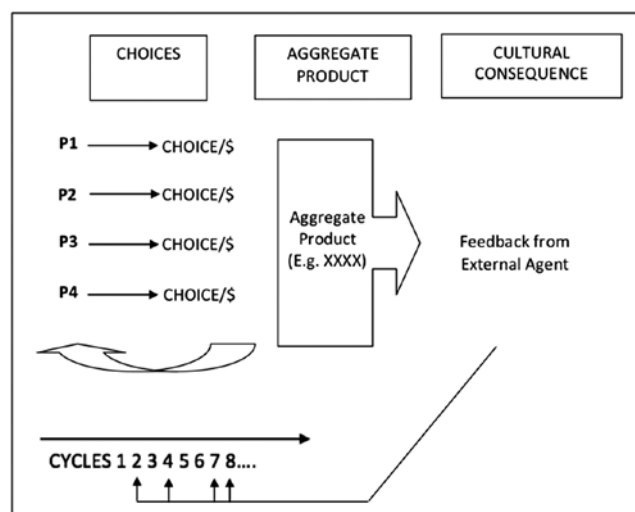


Figure 2. Outline showing interdependent operant consequences for individual player choices and cultural consequence contingent on aggregate product. In each cycle, each player presses X or Y and earns money. In addition, a cultural consequence in the form of money earned by the company is delivered as market feedback. The value of the market feedback is contingent on the aggregate product that has been produced by the four players.

Experimental Manipulation

A reversal design was used in all experiments. The independent variable was the metacontingency (contingent relations between specified aggregate products and market feedback). The metacontingency was the contingency between occurrences of aggregate products XXXX or YYYY and market feedback. The dependent variable was the aggregate products generated by the IBCs. The

feedback was delivered after a variable number of cycles, specifically, on average every second cycle. Importantly, the occurrence of feedback was not usually contiguous with the product that earned it, while the amount delivered was contingent on all products generated since the last feedback. No particular IBC (i.e. order of individual responses) was required by the contingency as long as the pattern produced the aggregate product specified.

For each cycle, the aggregate product determined the amount of money that entered into an invisible bank per player as shown in Figures 3 and 4. In XXXX conditions, the bank earned money only if all players pressed X, and losses were based on deviations from a product of all X's (Figure 3). In YYYY conditions the bank earned money only if all players pressed Y, and losses were based on deviations from a product of all Y's (Figure 4). Essentially, in the YYYY condition the amount of the cultural consequence (market feedback) was highest for the aggregate product that leads to the lowest global gain (28 cents overall, 7 cents each). On average every second cycle, the invisible bank was rounded to the nearest cent and distributed evenly among the players. The values in Figures 3 and 4 indicate the market feedback outcomes when the maximum amount of feedback possible per cycle per person was 10. This amount could be adjusted according to the following rules where "m" is the amount added to the bank per person for the cycle, "b" is the maximum, and "n" is the number of players who chose in accordance with the metacontingency in effect.

If $n > 3$, $m = b * n - 3$

If $n = 3$, $m = 0$

If $n < 3$, $m = b * - (3-n)/3$

The maximum market feedback was manipulated across experiments and sometimes within an experiment. We will refer to this maximum market feedback per person per cycle as "feedback maximum" or "maximum".

The criterion to switch from one condition to the next was at least 8 consecutive "correct" aggregate products. In both conditions, market gains and losses were shared equally among the players. The cumulative sum of money made by each player (individual gains + share of company gains already distributed) was shown in a window labeled "Score" located at the top left of the screen.

Condition XXXX (press X) Metacontingency		
Points Earned Individually	Aggregate Product	Cultural Consequence
7 7 7 7 (total 28)	YYYY	-10
4 11 11 11 (total 37)	XYYY	-6.6
8 8 15 15 (total 46)	XXYY	-3.3
12 12 19 19 (total 55)	XXXY	0
16 16 16 16 (total 64)	XXXX	10

Figure 3. Correspondences among Individual Earnings, Aggregate Products and Cultural Consequences in Condition XXXX. The column on the left, Money Earned, represents the amount of money in cents that each player gets if the combination of presses represented on the Aggregate Product column occurs in a cycle. The column on the far right, Cultural Consequence, represents the amount of feedback given by the external selecting agent contingent on the aggregate product.

Condition YYYY (press Y) Metacontingency		
Points Earned Individually	Aggregate Product	Cultural Consequence
7 7 7 7 (total 28)	YYYY	10
4 11 11 11 (total 37)	XYYY	0
8 8 15 15 (total 46)	XXYY	-3.3
12 12 19 19 (total 55)	XXXY	-6.6
16 16 16 16 (total 64)	XXXX	-10

Figure 4. Correspondences among Individual Earnings, Aggregate Products and Cultural Consequences in Condition YYYY. The column on the left, Money Earned, represents the amount of money in cents that each player gets if the combination of presses represented on the Aggregate Product column occurs in a cycle. The column on the far right, Cultural Consequence, represents the company earnings (feedback) given by the external selecting agent contingent on the aggregate product.

Experiment 1

Procedure

Experiment 1 was a preliminary investigation of the effect of feedback contingencies and feedback maximum on IBCs having XXXX or YYYY products. The metacontingency was manipulated holding the market feedback maximum at 10 for both XXXX and YYYY conditions, then at 25. The lack of consistent coordination in YYYY at market feedback 25 led the experimenter to gradually increase ("boost") the feedback maximum to determine if there was a value that would produce the YYYY product. Subsequently, the experimenter returned to the earlier values of market feedback and repeated the sequence of metacontingency conditions, eventually fading the market

feedback maximum until it reached zero (and feedback was discontinued) while in the YYYY condition.

Results

Figure 5 shows the results of Experiment 1. High variability in IBC products was seen at the outset of Experiment 1. In the first condition, the metacontingency between the XXXX product and market feedback with a maximum of 10 had no effect on aggregate products. In fact, XXXX was never produced, so players never even received positive market feedback for all pressing X. In the next condition (YYYY), all the players frequently pressed X, and even more frequently three of the four players pressed X. The metacontingency between the YYYY product and market feedback with a maximum of 10 had no effect, but the individual gains derived from all X presses appear to have maintained behaviour of pressing X.

When the feedback maximum was increased to 25 in the subsequent XXXX condition, the XXXX product became even more frequent and the condition ended with reliable production of XXXX. In the second YYYY condition, with feedback maximum of 25 contingent on production of YYYY, products became variable as market feedback consistently posted losses. Variability in products was seen through a series of increases in market feedback maximum

until the maximum reached 70, at which point the market feedback appears to have captured the IBCs that reliably produced YYYY.

When reduced to the feedback maximum of 10 in the third XXXX and YYYY conditions, market feedback maintained IBCs with products required by the metacontingency. In the fourth XXXX condition, a market feedback maximum of 25 maintained production of the XXXX product. In the fourth YYYY condition, the YYYY product was reliably produced even as the market feedback maximum was reduced from 25 to 0 and continued through the last condition in which there was no market feedback.

Discussion

Although the first four conditions were repeated in the second half of the experiment, the resulting data differ. Specifically, the second implementation of feedback maximums of 10 and 25 show clear control over aggregate products XXXX and YYYY, whereas only maximum 25 was initially effective, and even then only in the XXXX condition. The boost in market feedback maximum seems to account for the difference. Although YYYY production was not consistent until high maximum feedback was delivered contingent upon it, feedback maximums of 25 and 10 did sustain YYYY production after that pattern

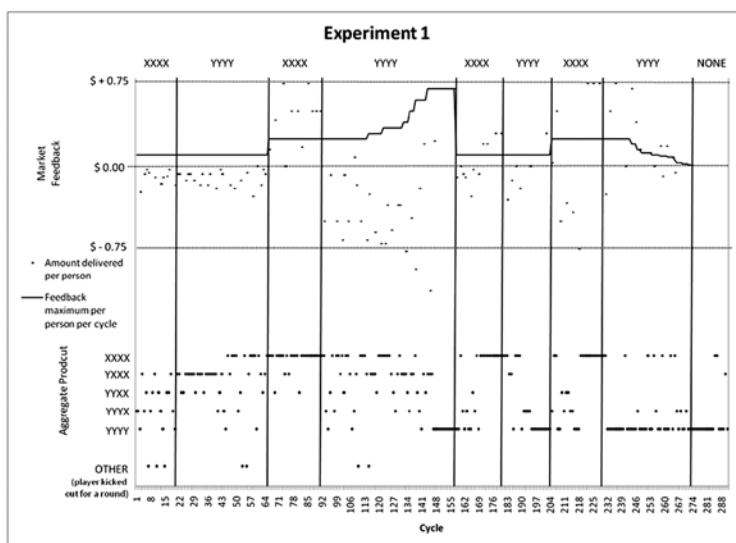


Figure 5. Results of Experiment 1. The bottom half of the graph displays the aggregate products produced by the group for each cycle. The x-axis represents sequential cycles, and the bottom half of the y-axis represents the aggregate products produced for 4 players or, if a player was kicked out, the occurrence of any 3-player product. The top section of the graph represents the activity of the market feedback. The points represent the positive and negative amounts of feedback per person that were delivered on a particular cycle contingent on aggregate products produced since the preceding feedback. The solid line represents the feedback maximum for that cycle.

was established. During the fade out of market feedback, and especially when the metacontingency was altogether broken at the end of the experiment, the YYYY production continued despite the very low earnings for all players. Such a stable YYYY pattern at the end of the experiment suggests that the effects of the earlier metacontingency persist for some time, much as operant responding persists for some time after the operant contingency is broken. This continuation is of particular interest because some or all players could earn more money, occasionally or reliably, by producing alternative patterns.

Experiments 2-5

Experiment 1 established that imposing metacontingencies in the form of market feedback contingent on the IBC products of XXXX or YYYY could result in emergence and systematic control over their production. Experiments 2 and 3 sought to further investigate the influence of metacontingencies on aggregate products by comparing market feedback conditions to conditions where no market feedback occurred.

Experiment 2 systematically replicated Experiment 1 by adding a baseline phase in which no market feedback was provided, adding a long return to baseline after market feedback reversals, and using fewer values of market feedback maximums. The purpose of the baseline and the long return to baseline was to see if the game itself would produce a consistent product without market feedback, to compare the products during market feedback conditions to those in the absence of market feedback, and to see how long a pattern of coordination after market feedback removal (such as that seen in Experiment 1) would last. Experiment 3 differed from Experiment 2 only because it entirely eliminated market feedback maximum adjustments.

Experiment 4 tested the necessity of the contingency in the market feedback delivery. Market feedback in Experiment 4 was not contingent on the aggregate products produced by that group. Instead, feedback was yoked to the feedback that had occurred in Experiment 3; it was delivered on the exact same cycles and in the same amounts as it had been in Experiment 3 regardless of the aggregate products produced in Experiment 4.

Experiment 5 investigated if small feedback maximums could maintain control over aggregate products. Feedback

maximum was adjusted to a sufficiently low value so that the aggregate products targeted by the metacontingency would produce suboptimal feedback for the group and for each individual.

Experiments 2 and 3 Procedures

Experiments 2 and 3 included a baseline condition with no market feedback, several reversals of the XXXX and YYYY conditions, and a return to baseline conditions. The experimenter transitioned from baseline to XXXX based on a judgment of stability in baseline. The other transitions still occurred once the aggregate product upon which positive market feedback was contingent (either XXXX or YYYY) occurred over 8 consecutive cycles, with the exception of the second transition in Experiment 3, which will be discussed below. The final condition was terminated according to the experimenter's judgment of stability. The market feedback maximum for both experiments was held steady at 10, with two brief exceptions in Experiment 2.

Experiments 2 and 3 Results

Figures 6 and 7 display the results of Experiments 2 and 3, respectively. In Experiment 2, baseline variation was initially high until XXYY became dominant in cycles 56 through 76. For the remaining cycles of the baseline condition (which ended on cycle 96), XXXY predominated. This XXXY pattern continued into the first XXXX condition, which meant that positive market feedback was never delivered in that condition. In order to induce variation and break this pattern, the experimenter boosted the market feedback maximum to 15 for a few cycles. However, the group had by this time stopped producing any product other than XXXY, possibly since that product avoided all negative market feedback under the XXXX contingency. This stringent pattern kept the market feedback at 0 even after the boost. For this reason, the experimenter changed the condition to YYYY so that the product XXXY would result in negative market feedback. After 51 cycles, products had not still varied sufficiently to produce YYYY and so the market feedback maximum was boosted to 15 again. Upon the first production of YYYY, the boost was removed and feedback maximum was returned to 10. The group then quickly met the 8-consecutive-trial criterion in the YYYY condition. Control of the product by the metacontingency became tighter throughout 5 more reversals, as seen by the shortening of transition periods and decreasing variation

within them. During the return to baseline, the YYYY pattern from the previous condition lasted for only 6 cycles, after which XXXX or YYYY products persisted but occurred less frequently than during market feedback conditions. Interestingly, the predominant patterns seen under the metacontingency (XXXX, YYYY or XXXY) comprised all but 26 of the 158 (84%) extinction cycles, though they were not produced in the same invariant way.

In Experiment 3, baseline again began with high variability, and market feedback conditions showed progressively tighter control over the products produced. In the first XXXX condition, variability continued for the first 20 cycles before consistent production of XXXX emerged. During the next (YYYY) condition, XXXX production continued for only 3 cycles followed by variation for 11 cycles and then a consistent production of YYYY. The second XXXX condition showed an even shorter period of variability. During the final YYYY condition, reliable production of YYYY began in the second cycle. During return to baseline, YYYY production continued for 16 of the first 25 cycles and 22 of the first 42 cycles. Substantial variation then characterized the remainder of this condition without market feedback, punctuated by bursts of XXXX production and an occasional YYYY.

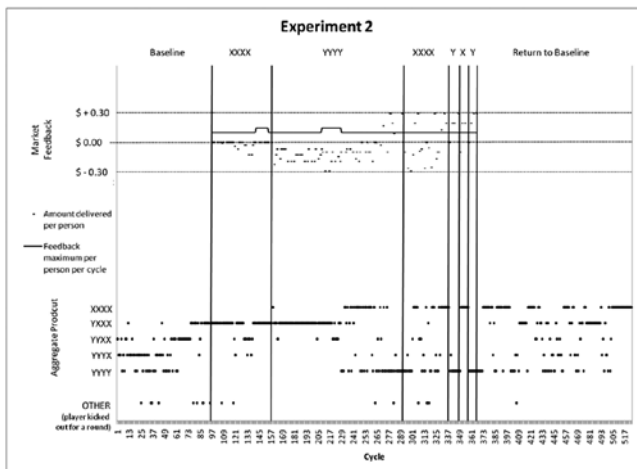


Figure 6. Results of Experiment 2.

Experiments 2 and 3 Discussion

Experiments 2 and 3 show that different proportions and patterns of aggregate products were produced during the IPDG game alone as opposed to the IPDG with a

metacontingency effect. Although XXXX coordination did increase through both baselines and remained strong in both returns to baseline, such conditions never produced the near-exclusive XXXX or YYYY production seen in the market feedback conditions. Thus, the findings of previous studies using prisoners' dilemma game are general to our setup; the individual contingencies embedded in the game itself do not reliably produce either XXXX or YYYY. The reliable production of these products under conditions of market feedback show that patterns unlikely to proceed from individual interactions alone can be produced through the application of a cultural consequence.

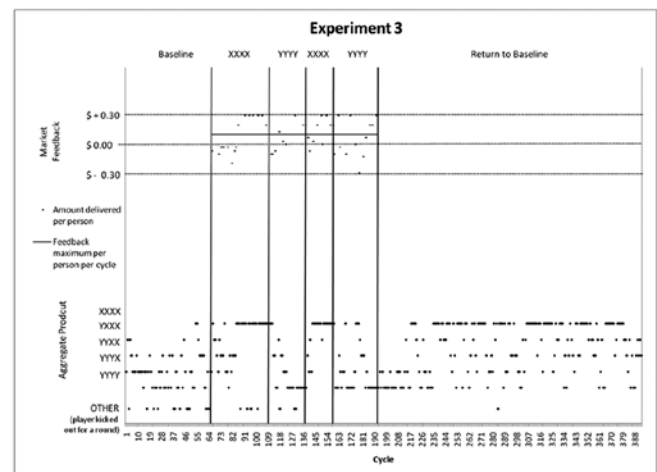


Figure 7. Results of Experiment 3

Experiment 4 Procedure

Procedures in Experiment 4 were identical to 2 and 3 except that market feedback, rather than being contingent on aggregate product, was yoked to the cycles in which feedback was delivered in Experiment 3. The purpose of Experiment 4 was to see if the metacontingency is necessary for selection of the aggregate product or if non contingent feedback itself is sufficient.

Experiment 4 Results and Discussion

Figure 8 shows the results of Experiment 4 as compared to its yoked Experiment 3. Baseline variation is similar to that of previous experiments, and during the yoked market feedback conditions this variation decreases. Unlike with the group from Experiment 3, this decreasing in variation does not proceed from more frequent production of

metacontingency targets. Instead, the products XXXY and XYYY appear to be favored, and the transition between them does not correspond to a changed condition from the yoked group. During the return to baseline, variation again increases.

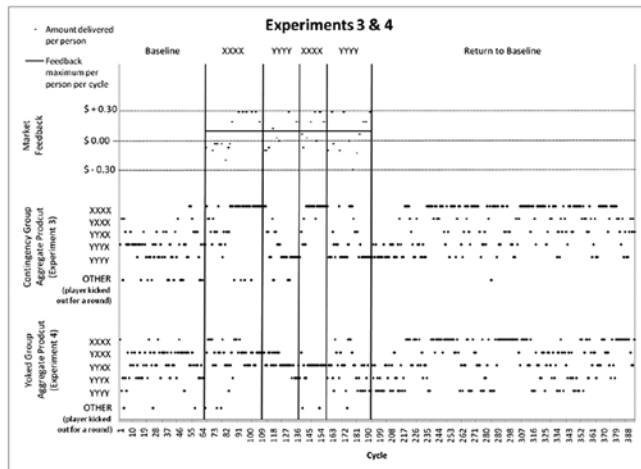


Figure 8. Results of Experiment 4 with cultural consequences yoked to contingent cultural consequences of Experiment 3.

Experiment 4 suggests that non contingent market feedback is not sufficient to control the production of particular aggregate products, but may adventitiously select certain products briefly and in a susceptible manner to drift.

Experiment 5 Procedure

Experiment 5 began with a similar baseline to Experiments 2-4. It imposed 4 reversals of market feedback conditions (XXXX-YYYY-XXXX-YYYY) with feedback maximum 4 instead of 10. This maximum was chosen because it is the highest possible that will never produce enough market feedback per person to make up for the individual points lost by choosing YYYY instead of XXXX in the YYYY condition (see Figure 9). The experimenter then lowered the feedback maximum to 3 for two reversals then to 2 for two reversals then to 1 for four reversals before returning to baseline.

Experiment 5 Results and Discussion

Figure 10 shows the results of Experiment 5. Baseline variation was similar to that seen in Experiments 2-4. The first four reversals at maximum 4 were sufficient to establish

control over aggregate products, and that control subsisted through all subsequent reversals, even at lower feedback maximums. As in previous experiments, transition states were shorter and generally showed less variation as reversals progressed, except for the last and third to last condition. Remarkably, the target product constituted all but 6 cycles of the final 4 conditions (when magnitude was 1). Of these 6 cycles, 4 occurred during XXXX conditions, when the metacontingency was not opposed to optimization. The YYYY condition showed YYYY production on all but 2 of the relevant cycles. This means that even when the group was losing 8 cents per cycle per person in the YYYY condition, the market feedback still retained control over aggregate product production. Notably, the return to baseline did not result in the typical variability; rather, XXXX was steadily produced.

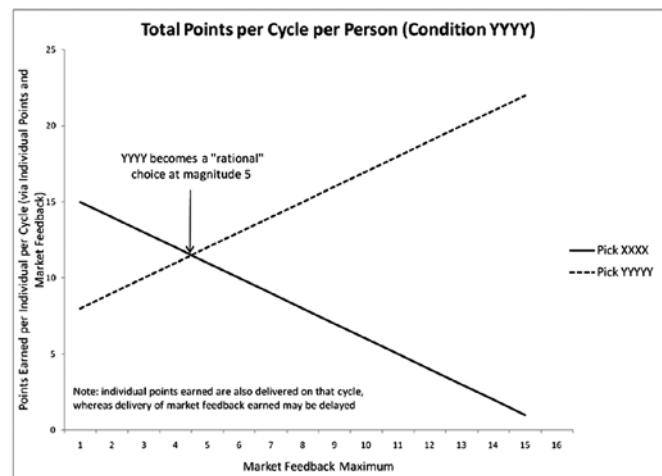


Figure 9. Shows the feedback maximum under which YYYY becomes more optimal than XXXX under the pick-Y (YYYY) condition in terms of global gain. At feedback maximums 5 and above, YYYY earns more on average per person per cycle than does XXXX when both individual and cultural consequences are considered. At feedback maximum 4 and below, YYYY produces suboptimal points compared to XXXX, even under the pick-Y condition.

Experiment 5 establishes that market feedback can maintain the production of aggregate products that provide suboptimal gains (both global and individual). This illustrates that selection does not necessarily produce perfect adaptation in all frames, and might even exert pressure in the opposite direction from an optimal solution. The potential of non-optimized selection has also been established on the behavioral level of analysis (Galbicka et al 1993).

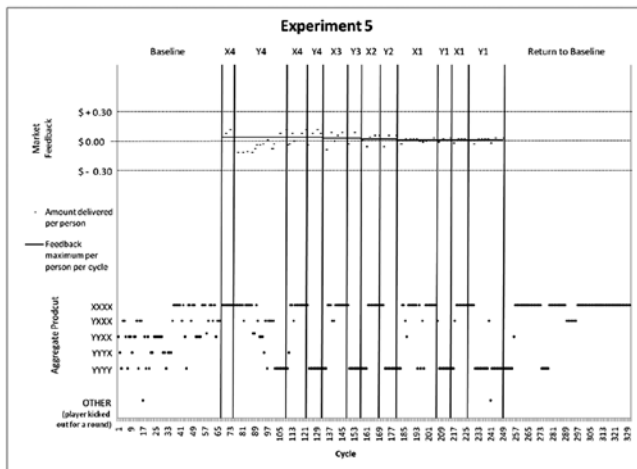


Figure 10. Results of Experiment 5.

General Discussion

Taken together, these experiments demonstrate a distinction between operant contingencies, which affect the behaviour of individuals, and metacontingencies, which affect interlocking behavioral contingencies in which multiple individuals participate. The mechanisms by which metacontingencies produce changes in IBCs and their products were not investigated in these experiments: a detailed descriptive analysis of interactions between players, such as their verbal interactions, was not conducted. It is not clear that such explanation is required any more than explication of neural changes is required to establish the functional relations of operant analyses. However, it is likely that changes in the behavioural contingencies occur as a function of metacontingency manipulations, which offers considerable opportunity for behaviour analysts to address occurring problems at system levels, above the level of individual organisms. Investigating the more microscopic level of interlocked behavioral contingencies could reveal useful information about cultural level influences, but interventions at the cultural level could reorganize those behavioral level contingencies with greater efficiency than a contrived behavioral intervention could provide.

References

- Bixenstine, V. E., Levitt, C. A., Wilson, K. R. (1966). Collaboration among six persons in a prisoner's dilemma game. *Journal of Conflict Resolution*, 10, 488-96.
- Bonacich, P., Shure, G., Kahan, J., Meeker, R. (1976). Cooperation and group size in the n- person prisoner's dilemma. *Journal of Conflict Resolution* 20, 687-706.
- Cooper, R. W., DeJong, D. V. & Forsythe, R. (1996). Cooperation without reputation: Experimental evidence from Prisoner's Dilemma games. *Games and Economic Behavior*, 12, 187-218.
- Dawes, R. M., (1980). Social dilemmas. *Annual Review of Psychology*, 31, 169- 193.
- Galbicka, G., Kautz, M., Jagers, T. (1993). Response acquisition under targeted percentile schedules: A continuing quandary for molar models of operant behavior. *Journal of the Experimental Analysis of Behavior*, 60, 171-184.
- Gallo, P., Jr., & McClintock, C. (1965). Cooperative and Competitive Behavior in Mixed-Motive Games, *Journal of Conflict Resolution*, 9 (1), 68-78.
- Glenn, S. S. (2004). Individual behavior, culture, and social change. *The Behavior Analyst*, 27, 133-151.
- Normann, H., & Wallace, B. (2011). The impact of the termination rule on cooperation in a Prisoner's Dilemma experiment. Available at SSRN: <http://ssrn.com/abstract=952953>
- Rapoport, A., Chammah, A., Dwyer, J., & Gyr, J. (1962). Three-person non-zero- sum nonnegotiable games. *Behavioral Sciences*, 7, 30-58.
- Selten, R., & Stoecker, R. (1986). End Behavior in Finite Prisoner's Dilemma Supergames, *Journal of Economic Behavior and Organization*, 1, 47-70.
- Schmitt, D. (1998). Social Behavior. In Lattal, K. & Perone, M. (Eds.), *Handbook of Research Methods in Human Operant Behavior*. (pp. 471-505). New York and London: Plenum Press.
- Skinner, B. F. (1957). *Verbal behavior*. Englewood Cliffs, NJ: Prentice-Hall.
- Vichi, C., Andery, M. A. P. A., & Glenn, S. S. (2009). A metacontingency experiment: The effects of contingent consequences on patterns of interlocking contingencies of reinforcement. *Behavior and Social Issues*, 18, 41-57.
- Yi, R. & Rachlin, H. (2004). Contingencies of reinforcement in a five-person prisoner's dilemma. *Journal of the Experimental Analysis of Behavior*, 82, 161-76.